

[CLAIMS]

[Claim 1]

A method of manufacturing a semiconductor device, comprising:

(a) loading a substrate with a film formed on a surface thereof into a process
5 vessel;

(b) generating a reactive species containing oxygen and a reactive species of a rare gas by converting a mixed gas containing the rare gas and an oxygen-containing gas into a plasma state; and

(c) oxidizing the film by supplying the reactive species containing oxygen to
10 the substrate together with the reactive species of the rare gas,

wherein, in (b), a partial pressure ratio P_N / P_T , which is a ratio of a partial pressure P_N of the rare gas in the process vessel to a total pressure P_T of the mixed gas in the process vessel, is selected within a range at which a wet etching rate of the film after being modified by sequentially performing (b) and (c) is equal to or less than a wet
15 etching rate of the film obtained by supplying, in (b), the reactive species containing oxygen to the substrate in the process vessel without supplying the reactive species of the rare gas thereto~~set to a value of 0.4 or less.~~

[Claim 2]

20 The method of claim 1, wherein, in (b), the partial pressure ratio P_N / P_T is set to a value of 0.2 or less.

[Claim 3]

The method of claim 1 or 2, wherein, in (b), the partial pressure ratio P_N / P_T is set to a value of 0.02 or more.

[Claim 4]

5 The method of claim 1 or 2, wherein, in (b), the partial pressure ratio P_N / P_T is set to a value of 0.04 or more.

[Claim 5]

10 The method of claim 1 or 2, wherein, in (b), the partial pressure ratio P_N / P_T is set to a value of 0.4 or less ~~selected within a range at which a wet etching rate of the film after being modified by sequentially performing (b) and (c) is equal to or less than a wet etching rate of the film obtained by supplying, in (b), the reactive species containing oxygen to the substrate in the process vessel without supplying the reactive species of the rare gas thereto.~~

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[Claim 6]

The method of claim 1 or 2, wherein, in (b), a hydrogen-containing gas is added to the oxygen-containing gas.

20 [Claim 7]

The method of claim 6, wherein at least one among oxygen gas and ozone gas is used as the oxygen-containing gas, and at least one among hydrogen gas and

deuterium gas is used as the hydrogen-containing gas.

[Claim 8]

The method of claim 1 or 2, wherein, in (b), a gas free of hydrogen is used as
5 the oxygen-containing gas.

[Claim 9]

The method of claim 1 or 2, wherein, in (b), helium gas is used as the rare gas.

10 [Claim 10]

The method of claim 1 or 2, wherein the film formed on the surface of the
substrate contains silicon.

[Claim 11]

15 The method of claim 10, wherein the film formed on the surface of the substrate
contains silicon oxide.

[Claim 12]

The method of claim 10, wherein the film formed on the surface of the substrate
20 contains silicon nitride.

[Claim 13]

The method of claim 1 or 2, wherein the film formed on the surface of the substrate contains one or more impurities selected from the group consisting of hydrogen, oxygen, water, carbon, nitrogen, phosphorus, sulfur, fluorine and chlorine.

5 [Claim 14]

The method of claim 1 or 2, wherein, in (b), a value of the partial pressure ratio P_N / P_T is adjusted by controlling a ratio of a flow rate of the rare gas supplied into the process vessel to a flow rate of the oxygen-containing gas supplied into the process vessel.

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[Claim 15]

The method of claim 1 or 2, wherein, in (b) and (c), a temperature of the substrate is 700 °C or higher.

15 ~~[Claim 16]~~

~~———— A method of manufacturing a semiconductor device, comprising:~~

~~———— (a) loading a substrate with a film formed on a surface thereof into a process vessel;~~

20 ~~———— (b) generating a reactive species containing oxygen and a reactive species of a rare gas by converting a mixed gas containing the rare gas and an oxygen-containing gas into a plasma state; and~~

~~———— (c) oxidizing the film by supplying the reactive species containing oxygen to the substrate together with the reactive species of the rare gas;~~

~~wherein, in (b), a partial pressure ratio P_N / P_T , which is a ratio of a partial pressure P_N of the rare gas in the process vessel to a total pressure P_T of the mixed gas in the process vessel, is selected within a range at which a wet etching rate of the film after being modified by sequentially performing (b) and (c) is equal to or less than a wet etching rate of the film obtained by supplying, in (b), the reactive species containing oxygen to the substrate in the process vessel without supplying the reactive species of the rare gas thereto.~~

[Claim 1647]

10 A substrate processing method comprising:

(a) loading a substrate with a film formed on a surface thereof into a process vessel;

(b) generating a reactive species containing oxygen and a reactive species of a rare gas by converting a mixed gas containing the rare gas and an oxygen-containing gas into a plasma state; and

(c) oxidizing the film by supplying the reactive species containing oxygen to the substrate together with the reactive species of the rare gas,

wherein, in (b), a partial pressure ratio P_N / P_T , which is a ratio of a partial pressure P_N of the rare gas in the process vessel to a total pressure P_T of the mixed gas in the process vessel, is selected within a range at which a wet etching rate of the film after being modified by sequentially performing (b) and (c) is equal to or less than a wet etching rate of the film obtained by supplying, in (b), the reactive species containing oxygen to the substrate in the process vessel without supplying the reactive species of

the rare gas thereto~~set to a value of 0.4 or less.~~

[Claim ~~17~~18]

A program that causes, by a computer, a substrate processing apparatus to
5 perform:

(a) loading a substrate with a film formed on a surface thereof into a process
vessel;

(b) generating a reactive species containing oxygen and a reactive species of a
rare gas by converting a mixed gas containing the rare gas and an oxygen-containing
10 gas into a plasma state; and

(c) oxidizing the film by supplying the reactive species containing oxygen to
the substrate together with the reactive species of the rare gas,

wherein, in (b), a partial pressure ratio P_N / P_T , which is a ratio of a partial
pressure P_N of the rare gas in the process vessel to a total pressure P_T of the mixed gas
15 in the process vessel, is selected within a range at which a wet etching rate of the film
after being modified by sequentially performing (b) and (c) is equal to or less than a wet
etching rate of the film obtained by supplying, in (b), the reactive species containing
oxygen to the substrate in the process vessel without supplying the reactive species of
the rare gas thereto~~set to a value of 0.4 or less.~~

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[Claim ~~18~~19]

A substrate processing apparatus comprising:

a process vessel in which a substrate is accommodated;

a transfer system configured to load the substrate into the process vessel;

a first gas supplier through which a rare gas is supplied into the process vessel;

a second gas supplier through which an oxygen-containing gas is supplied into the process vessel;

5 a plasma generator configured to convert a gas supplied into the process vessel into a plasma state;

an exhauster configured to exhaust an inner atmosphere of the process vessel;

and

a controller configured to be capable of controlling the transfer system, the first

10 gas supplier, the second gas supplier, the plasma generator and the exhauster to perform:

(a) loading the substrate with a film formed on a surface thereof into the process vessel;

(b) generating a reactive species containing oxygen and a reactive

15 species of the rare gas by converting a mixed gas containing the rare gas and the oxygen-containing gas into the plasma state; and

(c) oxidizing the film by supplying the reactive species containing oxygen to the substrate together with the reactive species of the rare gas,

wherein, in (b), a partial pressure ratio P_N / P_T , which is a ratio of a partial

20 pressure P_N of the rare gas in the process vessel to a total pressure P_T of the mixed gas in the process vessel, is selected within a range at which a wet etching rate of the film after being modified by sequentially performing (b) and (c) is equal to or less than a wet etching rate of the film obtained by supplying, in (b), the reactive species containing

oxygen to the substrate in the process vessel without supplying the reactive species of the rare gas thereto set to a value of 0.4 or less.